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Optimization of Multistage Collectors Using the MICHELLE Code Within the Analyst Modeling Framework*

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Abstract: *Using the MICHELLE Gun and Collector code linked to the Analyst finite-element modeling package, we have investigated the use of direct-search and statistical optimization strategies in the design of depressed collectors. Results of our work on an idealized device show that substantial improvements in efficiency can be realized using these methods.*

Keywords: optimization; depressed collectors; finite-element modeling.

Introduction

Depressed collectors used in modern microwave tubes are geometrically complex components that have a substantial impact on the operating characteristics of the device. Collectors are notoriously difficult to design, particularly for high-efficiency tubes, as there are often dozens of parameters that must be considered, including plate voltages, plate position and shape, and external field profiles. Of particular interest for high-efficiency collectors is maximizing energy recovery while minimizing the deleterious effects of secondaries.

The recent development of the MICHELLE code[1] has, for the first time, enabled the accurate modeling of depressed collectors in three-dimensions. Using the MICHELLE code hosted within the Analyst[2] finite element package, we have recently begun investigating the use of modern optimization algorithms in the design of multi-stage depressed collectors.

Approach

The primary method we have studied so far is the Nelder-Mead[3] direct search approach (a more robust realization of this method is the multi-directional search[4] (MDS) method), and the differential evolution technique[5]. In the Nelder-Mead/MDS methods a non-degenerate simplex of dimension n+1 is updated (for an n-dimensional parameter vector) at each step by testing new points along lines that are defined by the simplex edges. The volume enclosed by the simplex reduces until it encloses an extremum of the objective function.

In our present setup the actual execution of a particular algorithm is controlled by the Mathematica[6] symbolic manipulation program, which is linked to Analyst so that it can request analyses as necessary during the optimization (see Fig. 1). Analyst performs the required analyses by automatically constructing the 3D geometry based on the parameter list passed in by Mathematica, meshing the model, running MICHELLE, and extracting the relevant result quantities it then returns to Mathematica.

Results

We applied the optimization system to an idealized collector geometry shown in Fig. 2, using a specified spent-beam and magnetic field. Although the total efficiency that was achieved is not exceptional due to the exclusion of some design parameters, e.g., externally applied magnetic field variation, we found that it is possible to realize substantial improvements in collector efficiency as compared to un-optimized initial designs using both Nelder-Mead and differential evolution. Nelder-Mead generally requires somewhat fewer analyses than differential evolution to converge (Table 1 shows results for Nelder-Mead). The tendency of this approach to converge to local instead of global minima suggests that statistical methods like differential evolution are useful even if their overall computational efficiency is lower.

We will present details of our work on the idealized collector geometry discussed above, including results using our native implementations of both the MDS and differential evolution that eliminate the need for Mathematica.

References

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6. See www.wolfram.com for more details.

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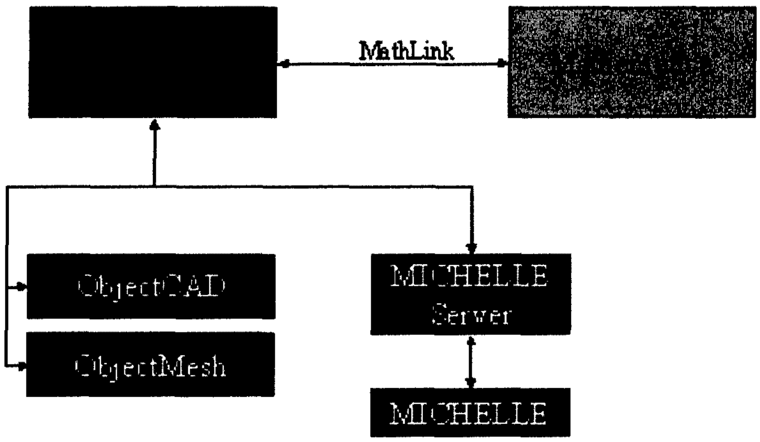

Figure 1. When a new analysis is requested by Mathematica, Analyst uses its embedded CAD and meshing servers to create geometry and generate the finite element mesh. The MICHELLE server is used to generate solver input files, run MICHELLE, and process the output files.

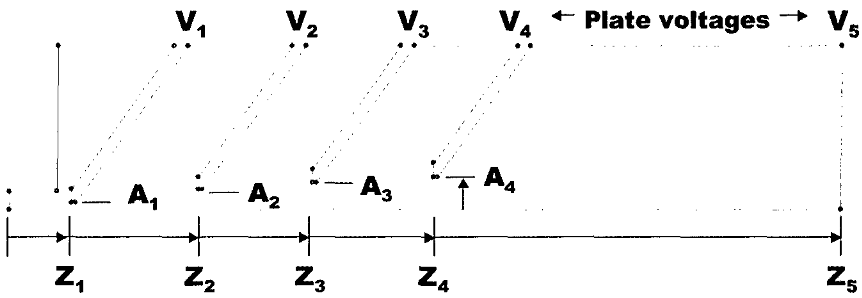

Figure 2. Idealized collector model. Parameters that were available for optimization included the plate voltages (V1-V5), the plate apertures (A1-A4), and the plate axial positions (Z1-Z5).

Step	Initial	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	All
Efficiency	**68.00%**	**74.60%**	**75.60%**	**77.80%**	**79.48%**	**80.13%**	**82.16%**
V1	-2327	-2508	-2508	-2508	-2508	-2508	-2492
V2	-3421	-3421	-3387	-3387	-3387	-3387	-3385
V3	-3987	-3987	-3987	-4377	-4377	-4377	-4385
V4	-4998	-4998	-4998	-4998	-5494	-5494	-5430
V5	-5750	-5750	-5750	-5750	-5750	-5594	-5646
Z1	0.1715	0.1544	0.1544	0.1544	0.1544	0.1544	0.1710
Z2	0.7339	0.7339	0.7173	0.7173	0.7173	0.7173	0.6938
Z3	1.0176	1.0176	1.0176	1.0902	1.0902	1.0902	1.0202
Z4	1.3244	1.3244	1.3244	1.3244	1.3773	1.3773	1.3550
Z5	2.2756	2.2756	2.2756	2.2756	2.2756	2.2323	2.3904
A1	0.0352	0.0491	0.0491	0.0491	0.0491	0.0491	0.0498
A2	0.1078	0.1078	0.1153	0.1153	0.1153	0.1153	0.1055
A3	0.1460	0.1460	0.1460	0.1470	0.1470	0.1470	0.1358
A4	0.1812	0.1812	0.1812	0.1812	0.1655	0.1655	0.1641
# of runs		57	46	39	36	39	261

Table 1. Parameter values and efficiencies for optimization of the collector geometry shown in Fig. 2 using the Nelder-Mead algorithm. The initial parameter values and corresponding efficiency are shown in column 2. The columns headed by "Stage n" show the results of the staged optimization where each stage was separately optimized. The final column shows the result when all parameters are used at once in a single optimization.